A Theory of Scientific Programming Efficacy

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Our Perspective

- Programming languages
- Software engineering
- Human-computer interaction
- Overall research question: how can we help people who write software be more effective?

Programming Languages Researchers Care About…

- Proving that programs are correct (what does "correct" mean?)
- Proving that programs don't have specific classes of bugs
- Making it easy to reason about programs
- Making programs run efficiently (faster, less energy)

What Should We Tell Scientists About How To Engineer Software?

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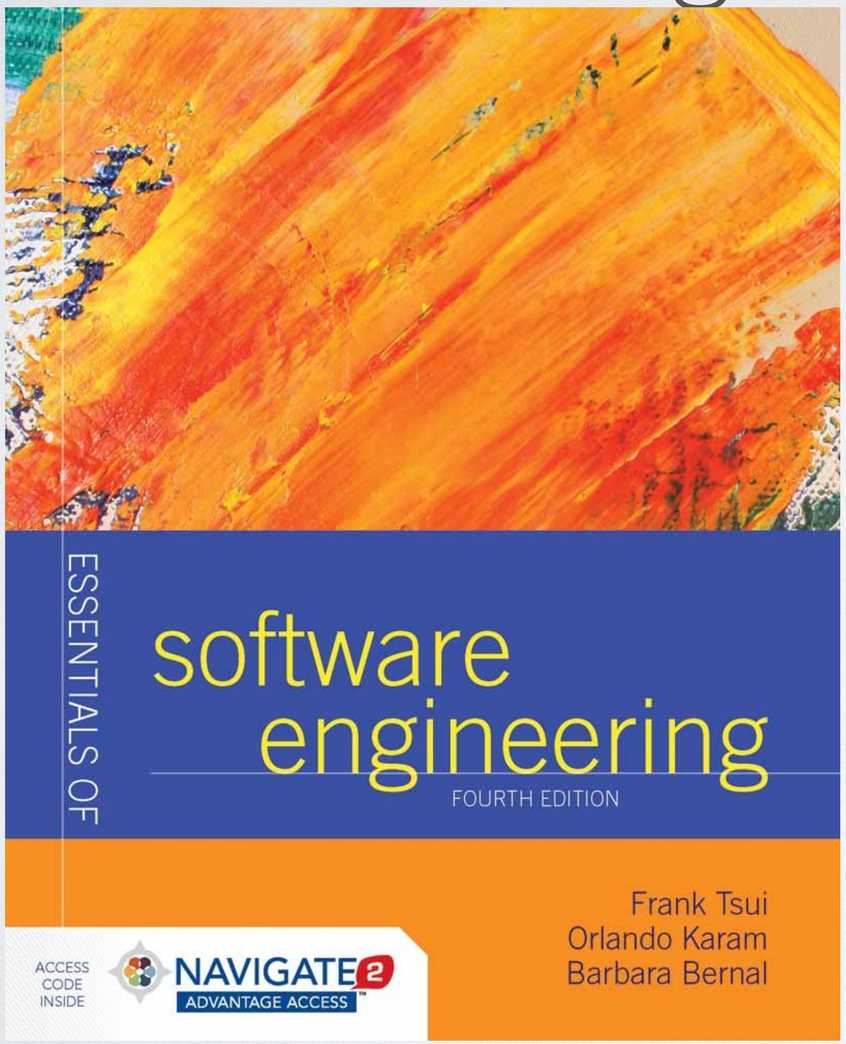

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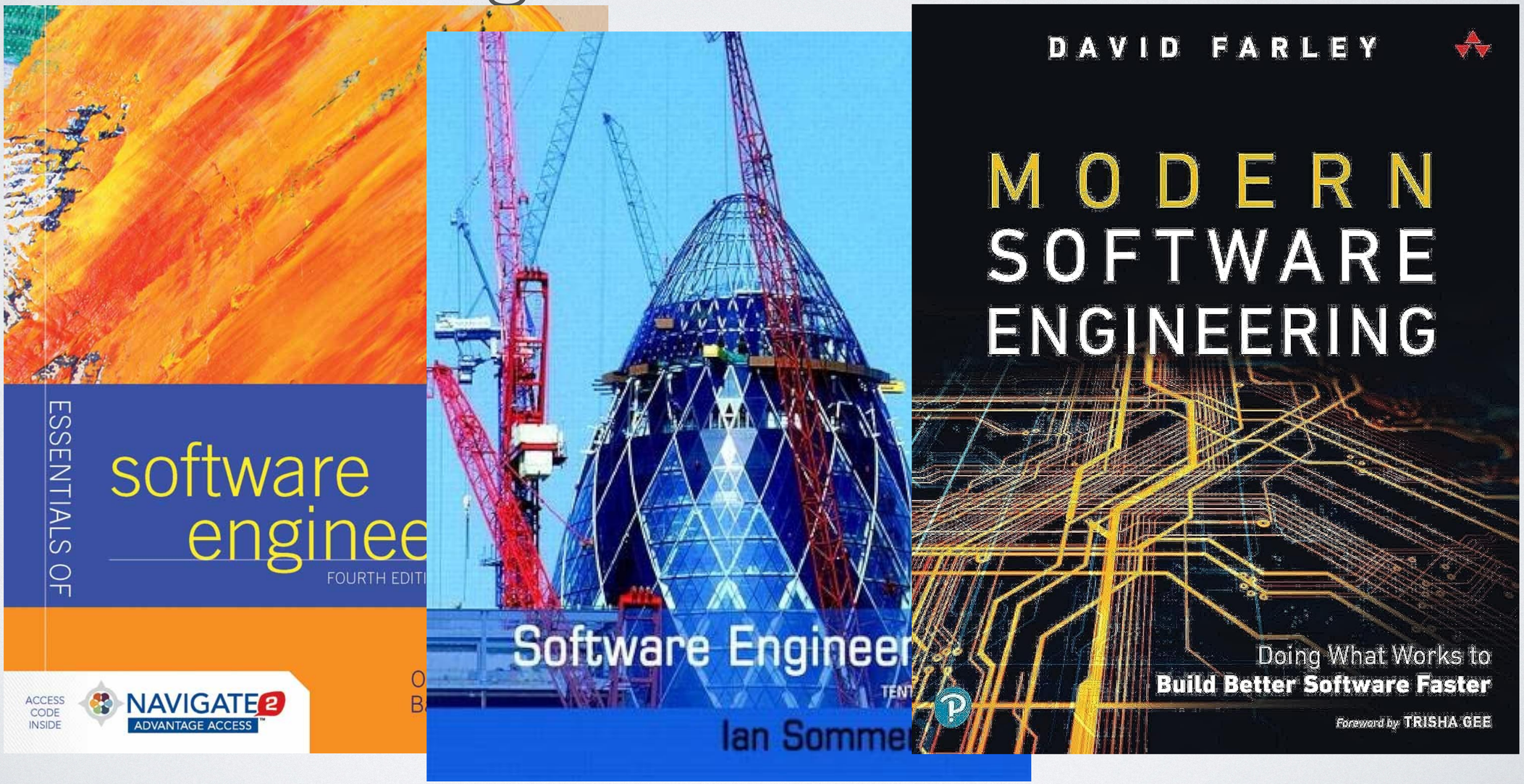


Assumptions of SE Research

- Software engineers:
  - have extensive training in programming
  - care about software
  - work in large teams to build large artifacts over a long time

For Scientists…

- Software is secondary (to results, papers)
- Programming background is inconsistent and potentially minimal
- Many small (< 10 KLOC) projects
  - that may leverage earlier projects

What Practices Lead to Effective Scientific Software Engineering?

- Interviewed 25 scientists about practices, challenges
- Used techniques from *grounded theory* to analyze transcripts
  - Qualitative research: goal is to hypothesize a theory, identify opportunities

Participants

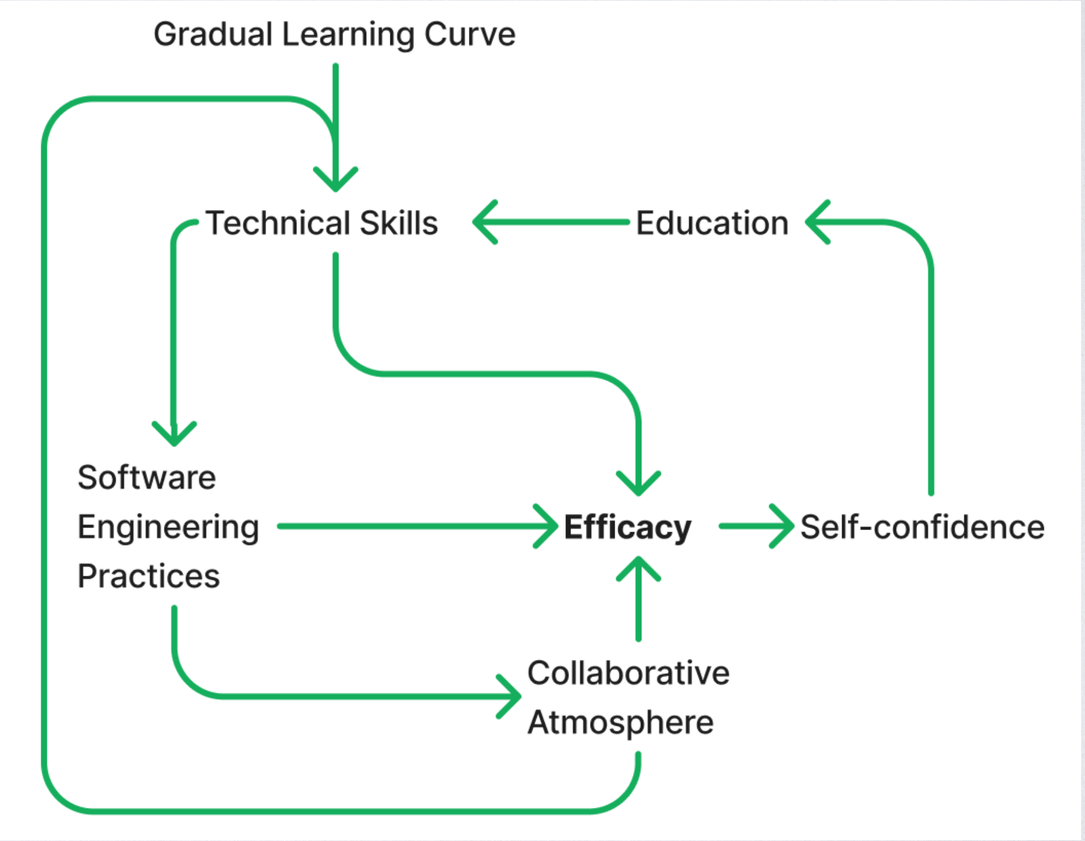
- 20 scientists
- 5 support staff

#	Field	Position	Education	Yrs.
P1	Oceanogr.	Post Doc	PhD Oceanogr.	8
P2	Oceanogr.	Proj. Scientist	PhD Oceanogr.	20
P3	Oceanogr.	Professor	PhD Oceanogr.	-
P4	Oceanogr.	PhD Student	BS Atmos. Sci.	5
P5	Econ.	Researcher	PhD Economics	22
P6	Oceanogr.	Researcher	PhD Oceanogr.	-
P7	Math.	Researcher	PhD Math.	10
P8*	Geosciences	Engineer	MS DSE	25
P9	Physics	Professor	PhD Physics	30
P10	Linguistics	PhD Student	MS Linguistics	-
P11	Climate Sci.	Post Doc	PhD Atmos. Sci.	-
P12*	HPC	User Support	PhD Aerosp. Eng.	-
P13*	HPC, Clim. Sci.	Research Staff	PhD Math.	45
P14	Bioinform.	Professor	PhD Comp. Sci.	20
P15	Clim. Sci.	PhD Student	BS Physics	5
P16	Oceanogr.	Lab. Director	PhD Physics	-
P17	Oceanogr.	PhD Student	BA Physics	4
P18	Oceanogr.	MS Student	BS Eng. Physics	6
P19	Econ.	Pre Doc	BS Econom.	3
P20	Econ.	PhD Candidate	BS Economics	-
P21	Bioinform.	PhD Student	BS Biology	3
P22	Glob. Policy.	Post Doc	PhD Atmos. Sci.	-
P23*	Research IT	SI Engineer	PhD Physics	20
P24	Oceanogr.	Post Doc	PhD Earth Sci.	11
P25*	Data Curation	Librarian	MLIS	7

Results

Efficacy

- Identified six factors that relate to efficacy
- Positive feedback loop: Self-confidence inspires more education, which promotes skills



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- 2/20 scientists in ongoing collaboration with multiple programmers
- Major opportunities here!

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- Sense of belonging to community is important for engagement, but scientists don't identify as software engineers

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- 17/20 reported apprehension or anxiety about programming
- 18/20 reported guilt over not following SE guidelines. "Oh I probably should be doing that . . . but I haven't had a reason to do [it]."

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- Low self-confidence may lead to desire for more formal education, which is unavailable (CS courses aren't a good match)

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- Heavy use of visualization libraries: "our histogram libraries are lovingly created…a little bit too much religion is involved in creating histogram libraries."

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- In contrast: Resnick's low floors, high ceilings, wide walls

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- Facilitate gradual learning via low-commitment formal education
  - Compare MOOCs (many small videos) to semester-long courses (monolithic)

PL Ideas To Consider

- Is functional programming a good match?
  - Can we make a functional PL that "looks" like Python?
  - Closer match to papers (math)?
- Auto-parallelization (for relevant programs)
- Automatic resource estimation (memory, storage, CPU)
- High performance (no GC or rare GC)

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